Lecture 4B (07/19/22)

Announcements

• Quest regrades due tonight!

• Midterm Logistics Post is Up (7/29)
Agenda

- A note on the path of least resistance
- Capacitors
- Capacitive Touchscreens
- Charge Sharing (life time)
Path of least resistance

- Current flows down the path of least resistance (WRONG)

- Current flows down all paths, but in an amount inversely proportional to the resistance of the path (correct)
Capacitors + Capacitance

Capacitance: 
\[ C = \frac{\varepsilon A}{d} \]
- \( C \) is capacitance in Farads (F)
- \( \varepsilon \) is permittivity of the dielectric
- \( A \) is the cross-sectional area
- \( d \) is the distance across

Resistance: 
\[ R = \frac{d}{A} \]
- \( R \) is resistance
- \( d \) is distance across
- \( A \) is area

Dielectric (insulator): 
- Represents the material between the electrodes
Capacitors: What's Happening

A electrons flow in the opposite direction of the labeled current
Capacitors: What's happening
Capacitors: Charging & Discharging

Charging (w/voltage)

\[ \frac{1}{t} \quad V = v_t - v_i \]
IV Relationship

\[ \text{charge on the plate (Coulombs)} \]

\[ Q = CV \]

\[ \frac{d}{dt} (Q = CV) \]

\[ I = C \frac{dV}{dt} \]

"element behavior"

Voltage drop

Capacitance
Example

\[ V_s = u_1 - 0 \]

\[ i_c = C \frac{dV_c}{dt} = C \frac{d}{dt}(u_1 - 0) \]

\[ i_c = C \frac{d}{dt} V_s \]

\[ i_c = OA \]
Example

\[ I = C \frac{du}{dt} \]
\[ i_c = C \left( \frac{du}{dt} (0 - u_1) \right) \]
\[ (u_1 - 0) = i_c R \]
\[ i_c = 0 = \frac{du}{dt} \]
\[ u_{ir} = 0 \Rightarrow u_1 = 0 \]

\[ i_c = 0 \] \text{steady state}
Example

\[ i_c = I_s \]
\[ i_c = C \frac{d}{dt} u_i \]
\[ I_s = C \frac{d}{dt} u_i \]
\[ u_i(+) = u_i(0) = \frac{I_s}{C} t \]
\[ u_i(+) = \frac{I_s}{C} t + u_i(0) \]
Example

Signal: independent source whose value is a function of time

\[ V_i(t+) = \frac{I_s}{C} t + V_i(0) \]
Capacitor Equivalence

**Series**
\[ C_{eq} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2}} \]

**Parallel**
\[ C_{eq} = C_1 + C_2 \]

\[ R = \frac{R_1 R_2}{R_1 + R_2} \]

\[ C = \frac{\varepsilon A}{d} \]
Example

\[ C_{eq} = \left( \frac{C_1}{C_2} \parallel \left( C_3 \parallel (C_4 + C_5) \right) \right) \]
Capacitive Touchscreens

- ~90% of touchscreens today
- More intricate hardware, but more control
Capacitive Touchscreens: No Touch
Capacitive Touchscreen: No Touch
Capacitive Touchscreens: With Touch

\[ C_2 \quad \frac{1}{C_0} \quad \frac{1}{C_1} \]

finger
Capacitive Touchscreens: With Touch

\[ C_{ef} = (C_1 + C_2) \times C_0 \]
Capacitive Touchscreen w vs wo touch

\[ V(t) = \frac{I_0}{C} t + V(0) \]

Graph showing the comparison between with and without touch, with the equation for voltage over time.
Charge Sharing

- Setup:
  - Circuit w/ voltage sources, capacitors and switches

![Circuit Diagram]

- $V_s$
- $C_1$
- $C_2$
- $\phi_1$
- $\phi_2$